CANADIAN JOURNAL OF RESEARCH

VOLUME 26 AUGUST, 1948 NUMBER 4

— SECTION C —

BOTANICAL SCIENCES

Contents

Page

Ascorbic Acid in Potatoes Grown in New Brunswick—*Elizabeth A. Baird and J. Lorne Howatt* - - - - - - - - 433

An Experiment to Measure Potential Evapotranspiration—*Marie Sanderson* - - - - - - - - - - - 445

Phosphorus Deficiency in Relation to the Nitrate Reduction Test. Comment on a Paper by Isobel Dimmick—*C. B. Taylor* - - - - - - - - - - - - - 455

NATIONAL RESEARCH COUNCIL
OTTAWA, CANADA

CANADIAN JOURNAL OF RESEARCH

The *Canadian Journal of Research* is issued in six sections, as follows:

A. Physical Sciences	D. Zoological Sciences
B. Chemical Sciences	E. Medical Sciences
C. Botanical Sciences	F. Technology

For the present, Sections A, C, D, and E are to be issued six times annually, and Sections B and F, twelve times annually, each under separate cover, with separate pagination.

The *Canadian Journal of Research* is published by the National Research Council of Canada under authority of the Chairman of the Committee of the Privy Council on Scientific and Industrial Research. The *Canadian Journal of Research* is edited by a joint Editorial Board consisting of members of the National Research Council of Canada, the Royal Society of Canada, and the Chemical Institute of Canada.

Sections B and F of the *Canadian Journal of Research* have been chosen by the Chemical Institute of Canada as its medium of publication for scientific papers.

EDITORIAL BOARD

Representing National Research Council	*Representing* Royal Society of Canada	
Dr. A. R. Gordon, (*Chairman*), Head, Department of Chemistry, University of Toronto, Toronto.	Dr. A. Norman Shaw, Chairman, Department of Physics McGill University, Montreal.	Section III
Dr. C. H. Best, The Banting and Best Department of Medical Research, University of Toronto, Toronto.	Dr. J. W. T. Spinks, Department of Chemistry, University of Saskatchewan, Saskatoon.	
Dr. Robert Newton, President, University of Alberta, Edmonton, Alta.	Dr. E. Horne Craigie, Department of Zoology, University of Toronto, Toronto.	Section V
Dr. G. H. Henderson, Professor of Mathematical Physics, Dalhousie University, Halifax.	Dr. H. S. Jackson, Head, Department of Botany, University of Toronto, Toronto.	

Ex officio	*Representing* The Chemical Institute of Canada
Dr. Léo Marion, Editor-in-Chief, Division of Chemistry, National Research Laboratories, Ottawa.	Dr. R. V. V. Nicholls, Associate Professor of Chemistry, McGill University, Montreal.
Dr. H. H. Saunderson, Director, Division of Information Services, National Research Laboratories, Ottawa.	

Editorial Committee

Editor-in-Chief,	Dr. Léo Marion	Editor, Section D,	Dr. E. Horne Craigie
Editor, Section A,	Dr. A. Norman Shaw	Editor, Section E,	Dr. J. B. Collip
Editor, Section B,	Dr. J. W. T. Spinks Dr. R. V. V. Nicholls	Editor, Section F,	Dr. J. A. Anderson Dr. R. V. V. Nicholls Dr. A. Norman Shaw
Editor, Section C,	Dr. H. S. Jackson		

Manuscripts should be addressed:

Editor-in-Chief,
Canadian Journal of Research,
National Research Council, Ottawa, Canada.

Canadian Journal of Research

Issued by THE NATIONAL RESEARCH COUNCIL OF CANADA

VOL. 26, SEC. C. AUGUST, 1948 NUMBER 4

ASCORBIC ACID IN POTATOES GROWN IN NEW BRUNSWICK[1]

BY ELIZABETH A. BAIRD[2] AND J. LORNE HOWATT[3]

Abstract

Values for the ascorbic acid content in the tubers of nine potato varieties have been compared. The effects of different fertilizers have been studied. Location of plots throughout the province was considered. Changes in ascorbic acid content due to tuber maturity and storage time have been measured at regular intervals. The relative amounts of ascorbic acid in the stem and eye ends of tubers have been found. Effects of top-killers on the ascorbic acid content of tubers were noted. No relationship was observed between the ascorbic acid content and either variety or fertilizer. The highest values for ascorbic acid were obtained in August. Losses during maturity and storage were continuous and fairly regular. Top-killers produced no apparent effect on the ascorbic acid content of tubers. The eye end of the potato tuber contained approximately 20% more ascorbic acid than the stem end.

Introduction

A survey has been made of the ascorbic acid content of certain commercial varieties of potatoes grown in New Brunswick.

The potato is one of New Brunswick's major crops. Accordingly, its food value and vitamin content assume a special significance in this province. The potato does not contain a high concentration of ascorbic acid but because of its widespread distribution and use it is one of the most valuable dietary sources of this vitamin.

The literature contains many conflicting findings in regard to the amounts of ascorbic acid in tubers of different varieties, as well as in tubers grown and stored under different conditions.

Esselen, Lyons, and Fellers (2) reported that the amount of ascorbic acid varied with variety, as well as with the season, but they found that geographical location had little or no effect on ascorbic acid content. On the other hand, Karikka, Dudgeon, and Hauck (3) observed varietal differences and also marked variation in ascorbic acid content among potatoes grown in different localities. Murphy (9) found differences in the vitamin C content of stored potatoes of different varieties. Lyons and Fellers (7) found differences within a variety to be greater than between varieties.

[1] *Manuscript received March 3, 1948.*

Contribution from the Department of Biology, University of New Brunswick, Fredericton, N.B. This work was made possible by a research grant to the University from Canadian Cottons, Limited.

[2] *Laboratory Assistant.*

[3] *Assistant Plant Pathologist, Dominion Laboratory of Plant Pathology, Fredericton, N.B.*

[The June issue of Section C (Can. J. Research, C, 26:219-431. 1948) was issued August 16, 1948.]

The effect of fertilizer has been studied extensively. Westas (19) found that fertilizer had no effect on the ascorbic acid concentration, as did also Scheunert, Reschke, and Kohlemann (15, 16) and Baker, Parkinson, and Lampitt (1). Nehring (11) claimed that the influence of single elements on vitamin C content had not been established. Later, Rangnekar (12) reported that up to a certain point vitamin C increased with an increase in manganese. Wachholder and Nehring (18) found that the ascorbic acid content was higher when potatoes were grown without fertilizer; but the Kentucky Agricultural Experiment Station Report No. 56 (4) showed that potatoes from plants receiving no fertilizer contained less ascorbic acid.

Nehring (11) and Wachholder and Nehring (18) suggested the importance of soil or local conditions other than fertilizer or variety in controlling the vitamin C concentration of potatoes. Lampitt, Baker, and Parkinson (5) found no significant difference in vitamin C concentration between potatoes of one variety grown on two types of soil.

Murphy (8) discussed the advantages and disadvantages of different storage temperatures. She recommended 50° F. for optimum retention of vitamin C. Karikka, Dudgeon, and Hauck (3) also favored 50° F. for storage.

The distribution of ascorbic acid in the tuber has also been the subject of several papers. Rolf (14) reported an uneven distribution and Murphy, Dove, and Akeley (10) spoke of the more concentrated bud end and the less concentrated stem end. Laurensen and Orth (6) found differences between the center and outer layers.

The effects of many other variables such as tuber maturity, size, shape, starch content, disease resistance, season, and locality have been discussed by many workers. Truscott, Johnstone, Drake, Van Haarlem, and Thomson (17) have considered several varieties in different years, both fresh and after storage. They found considerable variation between varieties and within varieties depending on the year of harvest.

Since no clear picture could be obtained from the literature it was felt that a survey of the ascorbic acid content of New Brunswick grown potatoes would be justified.

The work has been summarized in four parts, each part being considered separately. Generalizations follow, where possible.

Primarily, this survey was attempted in order to discover what differences, if any, could be observed in the ascorbic acid content of different varieties of New Brunswick potatoes under different conditions of growth and storage.

For the most part, the potatoes for this survey were grown at the Dominion Experimental Station at Fredericton. Those reported in Table III were grown in different localities throughout the province, but under the supervision of the Experimental Station.

The Green Mountain variety was chosen for all experiments except for the nine varieties reported in Table I.

All potatoes tested were from the 1946 crop. No weather records have been kept, although it is known that moisture and humidity have considerable effect on the size and nature of the tubers, so that indirectly the ascorbic acid may vary with the season. The potatoes were tested from July 1946 to August 1947.

Method of Storing

The potatoes were harvested in October. After harvesting the tubers were stored in bins at the Experimental Station until January when they were transferred to a temperature of about 40° F., with a variation of ± 2° F.

Method of Testing

The method of Roe (13) was used for determining the ascorbic acid in the potatoes. The procedure was that recommended for plant tissues. A weighed portion was ground in a Waring Blendor with 5% metaphosphoric acid containing 10% acetic acid. The extract was treated with acid-washed charcoal to oxidize the reduced ascorbic acid to dehydroascorbic acid. This extract and a standard solution of ascorbic acid were treated with dinitrophenylhydrazine, incubated for three hours at 37° C., and made up to volume with sulphuric acid. They were then compared colorimetrically, and the amount of ascorbic acid in the potato was calculated. This value included all the ascorbic acid present in either the reduced or oxidized form, but measured as dehydroascorbic acid.

Accordingly, for this paper, the term 'ascorbic acid' means the sum of 'converted' and 'free' dehydroascorbic acid.

A great many values for 'free' dehydroascorbic acid have also been obtained but these values have not been included in this paper.

Repeated recovery experiments and frequent testing of unknown standard solutions of ascorbic acid indicated that the tests were performed from day to day by the same workers during the whole period of investigation with an error not exceeding ± 5%.

Method of Sampling

Samples for analysis were prepared by chopping whole potatoes (including peel) into small pieces, using a plastic knife. After thorough mixing, a sample weighing 5 to 10 gm. was tested.

Method of Reporting

For each sample tested, percentage dry weights were obtained in duplicate by drying aliquots to constant weight in a drying oven at approximately 103° C. The values are reported in mgm. of ascorbic acid per 100 gm. of dry weight. The dry weight values have been used to express the changes in ascorbic acid independently of initial differences in moisture content or loss of water during storage. The percentage dry weights varied from 17 to 19% in July to 26 to 30% the following May.

Preliminary Observations

Early in the season, potatoes from separate hills were analyzed. Groups of four potatoes from each hill were tested. In addition a representative sample for the hill was obtained by mixing equal parts by weight from each of the four potatoes. Four old potatoes from the 1945 crop were tested in the same way, namely, separately and a representative mixture of all four. The old potatoes did not represent separate hills.

The mixture of potatoes consistently gave an average value for the lot within ± 5%. Values for individual potatoes varied over such a wide range that average values seemed more useful for this survey than individual values. The greatest range occurred among the young tubers. One hill, in July, contained a potato that exceeded the average value by as much as 32%.

At the close of the season, in August 1947, 25 potatoes, all from the same lot, were tested in groups of five, that is five potatoes separately and mixed. The values for the 25 potatoes ranged from 39.9 to 57.4 mgm. of ascorbic acid per 100 gm. of dry weight of potato, or a range of about ± 20%. Each group of five potatoes gave average values, within ± 5%.

The values recorded in the following tables are average values. Four or more potatoes were mixed for each estimation, wherever possible. Occasionally, only two or three potatoes were available.

Effect of Variety, Stage of Development, and Use of Top-killers on the Ascorbic Acid in the Potato Tuber

Table I shows the effect on the ascorbic acid content produced by three variables—namely, variety, stage of development before maturity, and effect of use of top-killers.

During the period of growth of potato tubers, from the first week in August until the middle of September, eight varieties were tested at weekly intervals. These were grown on eight plots, where, as far as possible, growth and treatment conditions were the same. A ninth variety was tested during the latter part of this period. All the potatoes from each hill were counted, measured, and weighed. The values represent average values for hills.

A parallel series was tested to estimate the possible effect of top-killers on the ascorbic acid content of tubers.

The practice of top-killing has recently found widespread favor in the growing of seed potatoes. The tops are killed by sprays as the tubers begin to approach maturity. This permits earlier harvesting of the crop, which may take place about two weeks after application.

Three lots of potatoes from these 'killed' plants were tested through the month of September. Control plants were provided by the eight varieties already being tested at weekly intervals during growth. Tubers were tested for ascorbic acid within one to three days from the time of digging.

The sprays used with the different varieties have been indicated in the table.

TABLE I

ASCORBIC ACID IN THE POTATO SHOWING EFFECT OF VARIETY, STAGE OF DEVELOPMENT, AND USE OF TOP-KILLERS

Variety	Tops green								Tops killed by sprays				
	Aug. 8	Aug. 12	Aug. 15	Aug. 19	Aug. 23			Sept. 5	Sept. 10	Sept. 5	Sept. 10	Sept. 25	Top-killer
					Large	Medium	Small						
1. Bliss Triumph	210*	183	187	191	172	152		144	142	176	160	150	Dowspray Early
2. Chippewa	183	188	177	127	106		136	114	155	157	124	121	Handy Killer
										127			
3. Earlaine	227	211	163	—		188		163	177	—	182	167	Dowspray
4. Green Mountain	161	135	172	113		131		127	133	126	129	101	Sinox
5. Houma	218	211	183	174	182	170		188	138	161	122	132	Dowspray
6. Irish Cobbler	195	150	173	170	155	128		127	136	136	130	140	Handy Killer
7. Katahdin	264	217	198	172	173		151	136	209	133	104	155	Dowspray Early
8. Sequoia	216	191	252	240	167		145	169	146	158	199	182	Dowspray Early
9. Sebago						178	152	182	230		172	120	Sinox

* *Ascorbic acid in mgm. per 100 gm. potato tissue (dry weight).*

The first potatoes were dug on Aug. 8. Some were tested on that day. The remainder were stored at 40° F. until Aug. 12, when they were tested for ascorbic acid. After four days' storage there was either a slight decrease or no significant increase.

Similarly the potatoes of Aug. 15 were tested on Aug. 15 and Aug. 19. Again storage produced either a slight decrease or no significant change in ascorbic acid.

On Aug. 23, large, medium, and small potatoes from each variety were tested separately. A variation of ± 12% was noted within each variety, but no definite trend was observed at this date to correspond with variation in size.

On Sept. 5 and 10 two fresh lots of potatoes gave values for ascorbic acid lower than those recorded in August.

Tubers from top-killed plants were tested on Sept. 5, 10, and 25. No control set was available for those tested on Sept. 25.

Table I shows that the highest values for ascorbic acid were observed in August, followed by a steady decrease at various stages of growth until harvesting. There was no significant change in the values after storage for four days. No variation could be attributed to size of tuber at this stage of maturity.

The variation between varieties on the same day was as great as ± 37% (from 113 to 240 mgm. ascorbic acid per 100 gm. of dry weight of potato); but there was no constancy of position for any one variety. The Katahdin variety, which occupied first place on Aug. 8, later fell to fourth place. On Sept. 5 it was sixth while on Sept. 10 it was in second place.

In general through this six weeks' period the Katahdin, Houma, Sequoia, Earlaine, and Sebago varieties ranked highest, the Bliss Triumph and Chippewa intermediate, and the Green Mountain and Irish Cobbler lowest. However, there was so much variation within each variety that it has been impossible to rank them in any definite order, to cover the whole period.

An average loss in ascorbic acid content of 25% was noted over this six weeks' period for all the varieties, with a range of loss from 15 to 37%.

Comparison of the ascorbic acid values in tubers from normal plants with those from plants killed by spraying showed no marked difference in the values, so that no effect could be traced to the treatment, at least during this time of observation.

Effect of Different Fertilizers and of Storage on the Ascorbic Acid Content of Potatoes

Table II shows the effects of fertilizers and of storage on the ascorbic acid content of potato tubers. It covers the period from July 1946 until the following May.

The different types of fertilizers and quantities are listed in the table. The Green Mountain variety of potato was used. Growth conditions were controlled so that as far as possible only the fertilizers varied.

Through July, August, and September average values were obtained for separate hills. From October to May the potatoes from different plots were stored in separate bins, at 40° F. By March, some of the tubers had started to sprout. The sprouts were removed from time to time, and analysis was done on tubers after removal of sprouts. The sprouts contained a considerable amount of ascorbic acid. No attempt has been made to explain the origin of this ascorbic acid nor to compare the total amounts in sprouted and unsprouted tubers.

During July and August the amount of ascorbic acid in the tubers was greatest, for all the fertilizers used. During September and October, while the tubers were still in the ground, the ascorbic acid decreased by as much as 25%. During storage the amount of ascorbic acid decreased until by the middle of December the value had fallen to about 50%. It continued to decrease until in May about 25 to 30% of the original amount remained, under these conditions of storage and regardless of the type of fertilizer.

During July and August the variation between different hills with the same fertilizer reached ± 19%. Variation between different fertilizers reached ± 20%.

Since the variation between different hills with the same fertilizer was as great as that between hills with different fertilizers no significant difference can be attributed to fertilizers.

During storage, when records of individual hills could no longer be obtained, monthly variations of plots with different fertilizers reached ± 27%. No single fertilizer gave consistently higher values than any other.

TABLE II

EFFECT OF DIFFERENT FERTILIZERS ON THE ASCORBIC ACID CONTENT OF POTATOES DURING GROWTH AND STORAGE

Plot No.	Fertilizer (per acre)	July 24	Aug. 2	Sept. 17	Oct. 8	Nov. 2	Nov. 12	Dec. 19	Mar. 18	May 27
1	1 ton 4-8-10 yearly from 1931	141* 155 149	182 136	145	144 153	127	98	78	83	47
2	½ ton 4-8-10 yearly from 1931	159 130	167 188 153	136	158 153	103	94	78	59	46
3	No fertilizer or manure since 1931	146 149 144	148 153 168 167	109	129	92	86	60	52	42
4	16 tons manure yearly since 1931	137 156 131 156	161 147 157	135	162	97	80	72	51	45
5	½ ton 4-8-10, 8 tons manure yearly since 1931	148 133 139	145 170 203	165	130	107	85	74	59	42
6-1	1 ton 4-8-10 basic, 3 year rotation		145 174 149	157	138	108	100	79	57	56
6-2	1 ton 4-8-10, 400 lb. 2-12-6				145	92	81	73	64	43
6-3	1 ton 4-8-10, 8 tons manure, new seeded land				142	97	95	79	63	44
6-4	1 ton 4-8-10, 8 tons manure, 500 lb. dolomite				143	81	86	68	62	45
6-5	1 ton 4-8-10, 500 lb. dolomite				152	95	82	75	65	48
6-6	No fertilizer or manure, 3 year rotation potatoes, grain, hay	134 150 155	158 137	135						

* *Ascorbic acid in mgm. per 100 gm. (dry weight).*

This study shows that the type of fertilizer used does not have any significant effect on the amount of ascorbic acid present in potatoes during growth. The rate of decrease during storage is independent of the fertilizer used.

Effects of Different Fertilizers in Different Localities on the Ascorbic Acid Content of Potatoes

The effect of fertilizer was further investigated together with the effect of storage as shown in Table III.

TABLE III

ASCORBIC ACID CONTENT OF POTATOES GROWN WITH DIFFERENT FERTILIZERS IN DIFFERENT LOCALITIES

Locality	Fertilizer	Amount per acre, tons	Other treatment	Harvested	Ascorbic acid in mgm. per 100 gm. (dry wt.)			
					Dec.	Jan.	Mar.	May
Centerville	0- 8-10	1		Sept. 24	117	78	64	39
	2- 8-10	1		" 24	103	72	49	41
	4- 8-10	1		" 24	118	75	54	40
	6- 8-10	1		" 24	128	74	—	36
	4- 4-10	1		" 24	73	66	50	51
	4-12-10	1		" 24	86	62	56	38
	4- 8- 5	1		" 24	96	63	61	30
	4- 8-15	1		" 24	83	61	60	35
	4- 8-10	½		" 24	112	79	39	34
	4- 8-10	¼		" 24	113	65	—	—
	4- 8-10	1		" 24	113	76	70	50
	None			" 24	83	81	71	48
Crockett	4- 8-10	1		Sept. 27	59	79	46	52
	4- 8-10	½		" 27	60	63	37	37
Guercherville	4- 8-10	1		Sept. 27	62	59	50	39
	4- 8-10	½		" 27	73	62	63	37
Mount Carmel	4- 8- 0			Sept. 20	62	67	48	38
	4- 8- 6			" 20	79	68	49	42
New Jerusalem	4- 8-10	1		Oct. 3	72	63	46	—
	4- 8-10	½		" 3	75	70	52	46
Saint Charles	None			Sept. 25	105	—	54	38
Saint Isidore	4- 0-10	¾		Sept. 19	80	73	44	36
	4-16-10	¾		" 19	58	69	52	48
Salisbury	4- 8-10	¾		Sept. 21	72	75	55	—
	None		Manure	" 21	68	56	51	41
Sandwith	4-16-10			Oct. 2	96	61	63	44
	4- 0-10			" 2	108	98	55	32
Seigas	4-10- 0			Sept. 26	66	55	58	40
	4-10-12	¾	Manure	" 26	54	69	45	37
	4-10- 6	¾	Manure	" 26	59	77	56	37

These potatoes were grown on 30 plots throughout the province with known fertilizers. Soils and natural conditions varied with the localities. The Green Mountain variety was used for all plots.

The tubers were harvested from Sept. 24 to Oct. 3. They were stored in Fredericton under the same conditions as the other potatoes used in this survey. They were tested in December, January, March, and May.

Centerville.—In December the potatoes from these 12 plots varied from 73 to 128 mgm. of ascorbic acid per 100 gm. of dry weight. These values represented a variation of $\pm$ 28%. This variation is of the same order as the $\pm$ 27% found in Table II.

Different fertilizers did not produce any apparent effects on the ascorbic acid content of the tubers.

No single plot produced potatoes that gave consistently high or low values during the whole period of observation. Plot No. 4, which gave the highest values for ascorbic acid in December had fallen to eighth place in May. Plot No. 9, which occupied sixth place in December, rose to second in January, and fell to 10th place in March and in May.

Crockett.—The values from these two plots were low in December but increased in January. The one ton of fertilizer generally produced higher values than the half ton per acre.

Guercherville.—In December, January, and March the plot with one-half ton of fertilizer gave potatoes with more ascorbic acid than those from the plot with one ton of fertilizer.

Mount Carmel.—These two plots showed practically no variation with fertilizers. In December the values ranged from 62 to 79 mgm. per 100 gm., but in January, March, and May there was no significant difference.

New Jerusalem.—In these two plots the one ton of fertilizer per acre gave lower values for ascorbic acid than the half ton.

Saint Charles.—This plot, which had no fertilizer treatment, gave potatoes with a high ascorbic acid content in December. Later in the season, average values prevailed.

Saint Isidore.—These two plots gave average values with both kinds of fertilizer.

Salisbury.—One of these fields was treated with manure instead of fertilizer. In January, potatoes from the field treated with manure gave a low value.

Sandwith.—Values from these two plots showed much fluctuation but no no consistent effect was observed.

Seigas.—Two of these three plots had manure treatment as well as fertilizer. The values in December were relatively low.

For this part of the survey values were obtained for the ascorbic acid content of potatoes grown on 30 plots. The tubers were tested four times during storage.

No correlation was observed between values for ascorbic acid content and either fertilizer or locality.

In December the values ranged from 54 to 128 mgm. per 100 gm. of dry weight. In January they ranged from 55 to 98 mgm. per 100 gm. In March the values were from 37 to 71, and in May from 30 to 52 mgm. per 100 gm.

No single plot gave values that were consistently high or low during the whole period of observation.

From December to May the values decreased by about 50%.

Value for Ascorbic Acid in Stem and Eye End of Tuber

During October and November values were obtained for the ascorbic acid content in the stem and eye ends of some potatoes of the Green Mountain variety. The values are listed in Table IV.

TABLE IV

ASCORBIC ACID IN THE STEM AND EYE ENDS OF GREEN MOUNTAIN POTATOES

Number	Date	Ascorbic acid in mgm. per 100 gm. (dry wt.)		Excess in eye end over stem end, %
		Stem end	Eye end	
1	Oct. 3	97	141	45
2	" 3	105	126	20
3	" 4	82	120	47
4	" 4	82	114	39
5	" 22	70	70	0
6	" 22	91	118	30
7	" 23	90	112	25
8	" 23	96	96	0
9	" 24	107	95	−11
10	" 24	70	101	45
11	" 25	81	109	35
12	" 25	82	74	−10
13	Nov. 4	101	82	−19
14	" 4	78	89	14
15	" 5	72	77	7
16	" 5	66	91	38
17	" 6	75	101	35
18	" 6	78	102	32
19	" 7	69	81	19
20	" 7	68	84	24
21	" 8	79	88	10
22	" 8	92	110	20
23	" 19	70	83	18
24	" 19	73	76	4
25	" 21	67	81	20
26	" 21	66	77	16

The eye ends were removed from the potatoes. They were chopped and thoroughly mixed. Similar representative samples were prepared from the stem ends of the same potatoes. Three to six tubers were included in each lot.

Twenty-six determinations were made. Twenty-one gave values for the eye end that were greater than those for the stem end, two were exactly the same, while only three had less ascorbic acid in the eye end than in the stem end.

The average excess of the ascorbic acid content in the eye end of the potato over the stem end was 20%. Statistical analysis of the values revealed that the excess of the eye end over the stem end was 15 mgm. per 100 gm. of dry weight. This excess was found to be significant.

This finding that the eye end of the potato contains a greater amount of ascorbic acid than the stem end is in agreement with results reported by Rolf (14) and by Murphy *et al.* (10).

It may be repeated here that for all the other determinations recorded in this paper, except those of Table IV, the potatoes were cut lengthwise, chopped, and mixed to obtain a thoroughly representative sample of whole tubers.

Conclusions

The amount of ascorbic acid in potatoes grown in New Brunswick was determined during the period of growth and subsequent storage for the 1946-1947 season.

Values for ascorbic acid were highest in August. They were approximately 150 to 200 mgm. of ascorbic acid per 100 gm. of dry weight of potato tissue. They decreased to about 50% of that value in December, and to about 25% of the original value by the following May.

Variation between different varieties reached ± 25%. No variety maintained either a high or a low value during the whole season.

Variation within the Green Mountain variety reached ± 27%, when the potatoes were grown with different fertilizers. In different localities, the variation reached ± 28%. No single fertilizer or no single locality produced tubers that remained consistently high or low.

The eye end of the potato contained more ascorbic acid than the stem end contained. The excess was about 20%. On statistical analysis the excess of the eye end over the stem end was calculated to be 15 mgm. per 100 gm. of dry weight. This excess was found to be significant.

From these observations no correlation was observed between ascorbic acid content of potatoes and either fertilizer or variety.

Acknowledgments

The authors wish to thank Mr. John M. F. MacKenzie and Mr. R. C. Parent, of the Experimental Station staff, for their co-operation in providing potatoes for this survey. Thanks are also extended to Dr. W. A. Andreae, Research Associate in Biology at the University of New Brunswick.

References

1. BAKER, L. C., PARKINSON, T. L., and LAMPITT, L. H. Vitamin C content of potatoes grown on reclaimed land. J. Soc. Chem. Ind. 65 : 428-430. 1946.
2. ESSELEN, W. B., JR., LYONS, M. E., and FELLERS, C. R. Composition and nutritive value of potatoes with special emphasis on vitamin C. Mass. Agr. Expt. Sta. Bull. 390. 1942.
3. KARIKKA, K. J., DUDGEON, L. T., and HAUCK, H. M. Influence of variety, location, fertilizer, and storage on the ascorbic acid content of potatoes grown in New York State. J. Agr. Research, 68 : 49-63. 1944.
4. KENTUCKY AGR. EXPT. STATION. Relation of time of applying fertilizer to content of ascorbic acid and of nitrogen in potatoes. Ann. Rept. Kentucky Agr. Expt. Sta. 56 : 39-40. 1943.
5. LAMPITT, L. H., BAKER, L. C., and PARKINSON, T. L. Vitamin-C content of potatoes. II. The effect of variety, soil, and storage. J. Soc. Chem. Ind. 64 : 22-26. 1945.
6. LAURENSEN, F. and ORTH, W. Distribution of ascorbic acid in potato tubers. Z. Untersuch. Lebensm. 83 : 193-206. 1942.
7. LYONS, M. E. and FELLERS, C. R. Potatoes as carriers of vitamin C. Am. Potato J. 16 : 169-179. 1939.

8. MURPHY, E. F. The vitamin C content of Maine foods. Maine Tech. Expt. Sta. Bull. 426 : 299-305. 1944.

9. MURPHY, E. F. Storage conditions which affect the vitamin C content of Maine-grown potatoes. Am. Potato J. 23 : 197-218. 1946.

10. MURPHY, E. F., DOVE, W. F., and AKELEY, R. V. Observations on genetic, physiological, and environmental factors affecting the Vitamin C content of Maine-grown potatoes. Am. Potato J. 22 : 62-83. 1945.

11. NEHRING, K. The effect of fertilization on the vitamin C content of potatoes. Congr. Intern. Tech. Chim. Ind. Agr., Compt. Rend. VI Congr. Budapest, 2 : 546-559. 1939.

12. RANGNEKAR, Y. B. Role of manganese in the formation of vitamin C and carotene in plants. Current Sci. 14 : 325. 1945.

13. ROE, J. H. and OESTERLING, M. J. The determination of dehydroascorbic acid and ascorbic acid in plant tissues by the 2,4-dinitrophenylhydrazine method. J. Biol. Chem. 152 : 511-517. 1944.

14. ROLF, L. A. The effect of cooking and storage on the ascorbic acid content of potatoes. J. Agr. Research, 61 : 381-395. 1940.

15. SCHEUNERT, A., RESCHKE, J., and KOHLEMANN, E. Über den Vitamin C-Gehalt der Kartoffeln. IV. Mitteilung: Über den Einfluss verschiedener Düngung. Biochem. Z. 305 : 1-3. 1940.

16. SCHEUNERT, A., RESCHKE, J., and KOHLEMANN, E. Über den Vitamin C-Gehalt der Kartoffeln. V. Mitteilung: Durchschnittsgehalt der deutschen Kartoffeln an Vitamin C vom Herbst bis zum Fungi. Biochem. Z. 305 : 4-21. 1940.

17. TRUSCOTT, J. H. L., JOHNSTONE, W. M., DRAKE, T. G. H., VAN HAARLEM, J. R., and THOMSON, C. L. A survey of the ascorbic acid content of fruits, vegetables and some native plants grown in Ontario, Canada. Dept. Natl. Health Welfare, Ottawa, Canada. 1946.

18. WACHHOLDER, K. and NEHRING, K. The influence of fertilizing and soil on the vitamin C content of potato varieties. Bodenkunde u. Pflanzenernähr. 16 : 245-260. 1940.

19. WESTAS, J. J. Factors influencing the vitamin C content of potatoes. Lantbrukshögskolans Ann. 9 : 285-293. 1941.

AN EXPERIMENT TO MEASURE POTENTIAL EVAPOTRANSPIRATION[1]

By Marie Sanderson[2]

Abstract

A method of obtaining daily values of the potential evaporating power of the atmosphere was used for the first time in Canada in 1947. The results verify Thornthwaite's formula for computing potential evapotranspiration in southern Ontario. The correlation between average runoff and computed water surplus for several watersheds in Ontario and Quebec is presented on a map.

The term potential evapotranspiration was introduced to climatological literature by C. W. Thornthwaite who defined it as the amount of water that will evaporate and transpire from a vegetation covered land surface while the root zone of the soil is well supplied with water. In his recent paper *An Approach Toward a Rational Classification of Climate* (3), Thornthwaite explains how he used existing experimental data to discover a relationship between potential evapotranspiration and other climatic factors for which there is abundant information. He devised a formula whereby water need can be computed for any station whose latitude is known and where temperature records are available. When the march of water need is compared with that of precipitation, periods of water surplus and water deficiency are revealed.

Thornthwaite used several kinds of information to test the reliability of his formula. Monthly figures of water use by irrigated crops were similar to the computed monthly water need, and average runoff for many eastern watersheds was the same as the average computed water surplus. In Canada average runoff was also compared with computed water surplus for watersheds containing weather stations (2). The correlation was surprisingly good, in view of the fact that the runoff is expressed in inches over the watershed and the water surplus is computed for a single point. The comparison between computed and measured runoff in southern Ontario and Quebec is presented in Fig. 1.

The best check on the formula and also a method of obtained daily values of potential evapotranspiration is to measure water need experimentally. Originally designed by Thornthwaite (4) for use in Mexico and called by the Mexicans an "evapotranspirometer", the apparatus was described by A. Contreras Arias in a recent Mexican Agricultural bulletin (1). During 1947 evapotranspirometers were installed in Mexico, in Toronto, Ont., and in Bridgeton, N.J.

[1] *Manuscript received April 21, 1948.*

Contribution from the Department of Physiography, Ontario Research Foundation, Toronto, Ont.

[2] *Research Fellow.*

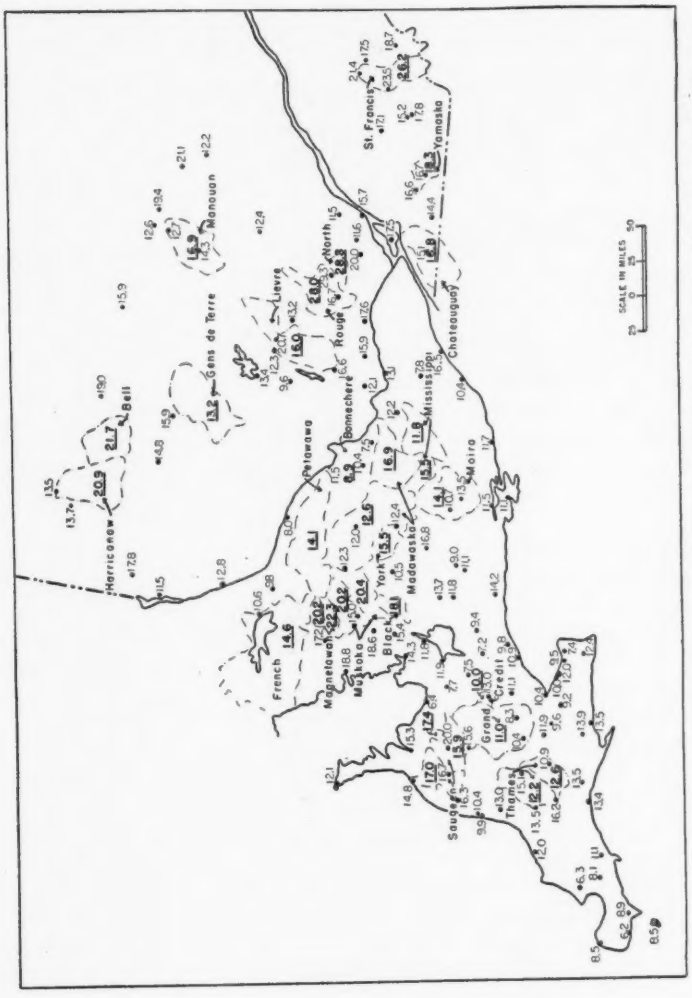

FIG. 1. *Average annual water surplus in southern Ontario and Quebec (in inches). Light figures represent water surpluses computed by Thornthwaite method from meteorological data. Heavier, underlined figures represent average runoff as measured by Dominion Water and Power Bureau.*

The present progress report describes a battery of evapotranspirometers installed by the Ontario Research Foundation at Toronto in June 1947, and gives all the observations obtained during the ensuing season.

Description of Experiment

A diagrammatic sketch of the evapotranspirometer used by the Ontario Research Foundation (modified from the original Thornthwaite apparatus by L. J. Chapman) is shown in Fig. 2.

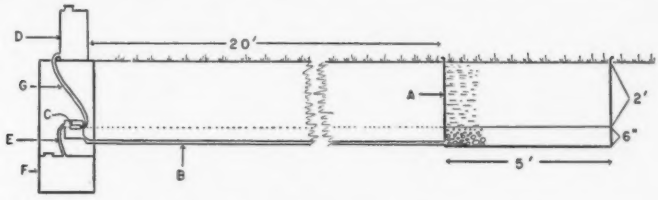

FIG. 2. *Diagrammatic sketch of evapotranspirometer.*

A. Galvanized iron tank (5 ft. × 5 ft. × 2½ ft.) buried in ground to within 2 in. of rim. Contains 6 in. of gravel, and filled with soil to ground level.*

B. Underground iron pipe connects tank A with the water supply mechanism (on left).

C. Carburetor float valve to maintain water level in tank A constant at 2 ft. below surface.

D. Five gallon reservoir from which water is supplied to the system through tube G. Filled with water to a fixed point each day.

Amount of water necessary to fill reservoir is thus a measure of the daily water loss from tank A.

E, F. Mechanism to allow overflow. When rain occurs, and water level in A rises, intake from tank D is cut off by float value; water reverses its flow, and empties, by means of copper tube E placed just above water level, into overflow tank F.

A distance of 20 ft. separates tank A from the measuring apparatus, so that the microclimate of the tank is little affected by this protuberance.

** Soil used was a natural sandy loam with good capillarity, a moisture equivalent of 15.0 and mechanical analysis as follows:*

Tank	*% coarse sand*	*% fine sand*	*% silt*	*% clay*
A	*22*	*23*	*39*	*16*
B	*19*	*36*	*33*	*12*
C	*21*	*29*	*35*	*15*
D	*17*	*32*	*36*	*15*

The principle is simple: to keep a grass-covered area, with natural microclimatic conditions, constantly supplied with water by subirrigation: and to measure the daily water use. Since the soil is kept constantly moist, it is assumed that the plants will use all of the water they want and that evapotranspiration will depend solely on atmospheric conditions. Four tanks were installed. Two of the tanks were planted with crested wheat, a drought resistant grass, and two with timothy, a grass believed to have a high moisture requirement.

The location chosen for the experiment was Mount Pleasant cemetery in North Toronto (latitude 49° 40′ N., altitude 500 ft.). It was selected since it contained the most accessible, large, open area within a few miles of the Ontario Research Foundation. Fig. 3 shows the actual site, chosen because

of its accessible water supply, and fairly level ground. The site is open to the winds on the three sides, but there is a small wooded area about 100 ft. to the north. The immediate surroundings were sown to rye, which was cut periodically during the summer, providing an excellent meadowlike environment. The grass was clipped in the tanks and the surrounding plot every few weeks, to keep it about 2 to 4 in. high, and prevent it from going to seed. During dry periods, the grass in the surrounding plot was watered to ensure continued growth.

Readings were taken daily at 8.00 A.M. Eastern Standard Time of the following:

1. The amount of water (in liters) necessary to fill each intake tank.
2. The precipitation, if any, caught in the rain gauge (in millimeters).
3. The overflow (in liters), if any, collected in the overflow tank.
4. The maximum and minimum temperature for the preceding 24 hr.

Water entering the soil of the evapotranspirometer comes either from the intake tank or from precipitation. Water can leave the tank only by overflowing into the overflow tank, or by upward transfer as water vapor into the air. The latter is the evapotranspiration that may be obtained as a difference.

$$E = P + I - O$$

where E is evapotranspiration, P is precipitation, I is intake, and O is overflow.

Primary Observations

The daily readings for the five months while the transpirometers were in operation are given in Table I. The surface of the soil in the tanks remained moist throughout the season, and it is certain that the vegetation had all the moisture that it required. Nevertheless, the overflow worked well; when rain occurred and the ground water level in the tank rose, water backed up through the pipe, closed the float valve cutting off the supply of water from the intake tank, and then overflowed into the overflow tank. The observations appear to be reliable, and indicate the daily water loss from a grass covered area under approximately natural conditions.

There was no significant difference in the daily water use by timothy and crested wheat grass. The water loss was the same for all four plots, even at the beginning of the season, when the timothy provided a dense lush cover and the crested wheat grass cover was sparse. There was reason to expect sizeable variations in the daily readings of the four tanks even after it became apparent that the species of grass and the amount of soil exposed made little difference. The soil, of course, was not identical in the tanks (Fig. 2) and capillarity could vary. Nevertheless, the variations were not great. In 75% of the readings uncomplicated by precipitation, the variation for the 24 hr. period was less than 1 liter or 0.44 mm. expressed as water loss from the surface of the tanks. For 35% of the time, the variation was less than 200 cc. or 0.09 mm.

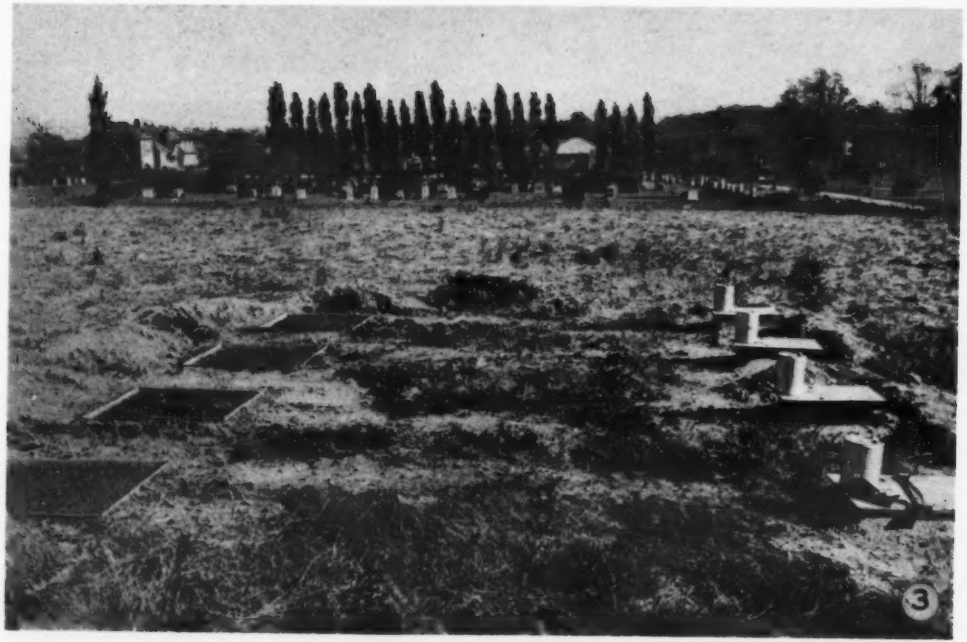

FIG. 3. *Ontario Research Foundation potential evapotranspirometers, Mount Pleasant, Toronto, June, 1947. Transpirometer tanks at left, not yet seeded.*

TABLE I

DAILY VALUES OF EVAPOTRANSPIRATION—TORONTO, 1947

Date	Temperature			P (mm.)	Water added (mm.)				Overflow (mm.)				Evapotranspiration (mm.)				
	Max.	Min.	Mn.		A	B	C	D	A	B	C	D	A	B	C	D	Computed
June 25	74.0	61.1	67.5	0.76	3.32	3.38	3.66	2.78	0.35	0.33	0.33	0.33	3.73	3.81	4.09	3.21	4.12
26	78.4	57.1	67.7		3.36	3.38	3.56	3.89					3.36	3.38	3.56	3.89	4.20
27	80.0	60.0	70.0		4.34	4.35	4.75	–					4.34	4.35	4.75	–	4.50
28	83.0	64.1	73.6		4.82	4.95	5.03	4.91					4.82	4.95	5.03	4.91	4.90
29	85.5	67.6	76.6		4.80	4.85	4.85	4.76					4.80	4.85	4.85	4.76	5.40
30	84.6	68.2	76.4		5.14	5.11	5.25	5.22					5.14	5.11	5.25	5.22	5.40
July 1	75.5	60.3	67.9		4.52	4.26	4.50	4.60					4.52	4.26	4.50	4.60	4.30
2	70.5	57.0	63.8		5.00	4.90	4.76	4.60					5.00	4.90	4.76	4.60	3.70
3	78.0	55.2	66.6		4.28	4.44	4.58	4.74					4.28	4.44	4.58	4.74	4.00
4	83.5	57.5	70.5		5.35	5.34	5.25	4.82					5.35	5.34	5.25	4.82	4.48
5	79.5	62.5	71.0	7.11	0.98	0.89	1.28	0.44	3.98	3.56	3.98	2.21	4.11	4.44	4.41	5.34	4.61
6	79.5	62.5	71.0	11.68	0.84	1.05	1.41	1.33	8.86	8.02	8.35	6.20	3.66	4.71	4.74	6.81	4.61
7	73.5	57.0	65.2		3.05	2.52	–	–					3.05	2.52	–	–	3.84
8	74.0	61.0	67.5		2.88	3.02	–	2.70					2.88	3.02	–	2.70	4.09
9	73.5	61.0	67.2		3.90	3.72	3.48	3.25					3.90	3.72	3.48	3.25	4.06
10	80.3	61.5	70.9	0.25	4.55	4.75	4.42	4.20					4.80	5.00	4.67	4.45	4.55
11	79.2	63.0	71.1		4.55	4.55	4.32	4.25					4.55	4.55	4.32	4.25	4.57
12	80.7	61.5	71.1	8.13	1.55	1.42	2.20	1.41	6.08	4.66	5.95	3.98	3.60	4.89	4.38	5.56	4.57
13	84.0	66.0	75.0		3.05	2.93	2.82	2.12					3.05	2.93	2.82	2.12	5.08
14	82.2	64.8	73.5	17.27	4.11	4.00	3.62	3.01	14.20	12.60	11.90	8.85	7.18	8.67	8.99	11.43	4.83
15	77.8	65.5	71.6	2.79	1.06	0.80	0.66	0.09	1.77	1.87	2.56	2.88	2.08	1.72	0.89	0	4.54
16	80.4	67.4	73.9		2.65	2.53	2.86	1.50					2.65	2.53	2.86	1.50	4.92
17	82.2	65.0	73.6	2.03	1.68	1.60	1.68	1.24	0.53	0.09	1.06	0.13	3.18	3.54	2.65	3.14	4.79
18	83.0	57.0	70.0	2.29	1.15	1.46	1.28	1.06	0.66	0	0.44	0.09	2.78	3.75	3.13	3.26	4.40
19	65.6	48.0	56.8		2.88	2.84	2.39	2.30					2.88	2.84	2.39	2.30	2.77
20	73.8	57.0	65.4	8.89	4.78	4.99	4.36	3.76	5.75	4.65	5.32	3.32	7.92	9.23	7.93	9.33	3.75
21	70.0	57.4	63.7		0.93	0.71	0.58	0.04					0.93	0.71	0.58	0.04	3.50
22	62.5	52.8	57.6	32.00	0.26	0.31	0.18	0.31	28.70	27.40	26.60	24.35	3.56	4.91	5.58	7.96	2.75
23	67.8	54.7	61.2		1.33	0.62	0.40	0.09					1.33	0.62	0.40	0.09	3.22
24	79.8	57.5	68.6		4.55	4.12	11.00	2.68	0.22	0.66	10.30	2.68	4.33	3.46	0.70	0	4.10
25	83.2	59.0	71.1		4.65	4.62	5.50	4.07					4.65	4.62	5.50	4.07	4.46
26	82.4	64.0	73.2		3.72	3.87	3.67	3.76					3.72	3.87	3.67	3.76	4.70
27	69.0	61.0	65.0	41.40	0	0	0	0	38.90	36.40	35.20	33.90	2.50	5.00	6.20	7.50	3.70
28	80.0	61.0	70.5		2.21	1.87	1.58	0.80					2.21	1.87	1.58	0.80	4.30
29	88.8	67.5	78.1		4.70	4.61	4.27	3.78					4.70	4.61	4.27	3.78	5.29
30	85.0	63.0	74.0		4.91	5.34	4.87	4.75					4.91	5.34	4.87	4.75	4.75
31	71.0	46.0	58.5		5.35	5.35	5.48	5.05					5.35	5.35	5.48	5.05	2.80
Aug. 1	67.0	47.0	57.0		4.86	5.02	4.76	4.83					4.86	5.02	4.76	4.83	2.69
2	74.1	54.2	64.1		4.07	4.13	4.00	4.25					4.07	4.13	4.00	4.25	3.54
3	80.8	59.0	69.9		4.60	4.76	4.48	4.60					4.60	4.76	4.48	4.60	4.26
4	82.8	60.2	71.5		5.32	5.20	5.30	5.45					5.32	5.20	5.30	5.45	4.36
5	84.8	63.5	74.1		4.78	5.29	4.72	5.05					4.78	5.29	4.72	5.05	4.72
6	87.2	62.6	74.9		4.37	4.50	5.07	4.83					4.37	4.50	5.07	4.83	4.80
7	86.9	66.0	76.4		4.74	4.98	4.76	5.14					4.74	4.98	4.76	5.14	5.04
8	83.0	65.5	74.3		2.61	2.91	2.82	3.21					2.61	2.91	2.82	3.21	4.64
9	81.0	59.2	70.1		4.38	–	4.45	4.60					4.38	–	4.45	4.60	4.17
10	81.0	64.0	72.5		5.68	–	5.67	5.53					5.68	–	5.67	5.53	4.37
11	85.6	64.2	74.9		3.54	–	4.03	4.00					3.54	–	4.03	4.00	4.72
12	93.2	71.0	82.1		3.54	–	3.46	3.67					3.54	–	3.46	3.67	5.55
13	93.0	73.0	83.0		4.25	–	4.43	4.56					4.25	–	4.43	4.56	5.73
14	91.5	69.5	80.5		1.88	–	1.72	2.04					1.88	–	1.72	2.04	5.38
15	77.5	62.2	69.9	5.59	0.89	–	0.79	0.53	1.79	–	0	0.44	4.69	–	6.38	5.68	4.10
16	77.8	59.0	68.4		4.45	–	4.52	4.31					4.45	–	4.52	4.31	3.83
17	78.0	66.0	72.0		2.78	–	3.13	3.28					2.78	–	3.13	3.28	4.29
18	89.5	69.0	79.3	10.67	3.52	–	3.62	3.54	8.05	–	7.85	4.20	6.14	–	6.44	10.01	5.18

TABLE I—*Continued*

DAILY VALUES OF EVAPOTRANSPIRATION—TORONTO, 1947—*Continued*

Date	Temperature			P (mm.)	Water added (mm.)				Overflow (mm.)				Evapotranspiration (mm.)				
	Max.	Min.	Mn.		A	B	C	D	A	B	C	D	A	B	C	D	Computed
Aug. 19	84.5	68.5	76.5	9.40	0	–	0	0	9.70	–	9.40	9.40	−0.30	–	0	0	4.83
20	77.8	67.5	72.6		1.10	–	0.93	0.38					1.10	–	0.93	0.38	4.26
21	79.3	69.0	74.2		1.41	–	1.41	1.22					1.41	–	1.41	1.22	4.50
22	78.9	54.2	66.5		2.39	2.48	2.57	2.35					2.39	2.48	2.57	2.35	3.54
23	81.4	66.9	74.1		3.28	3.32	3.36	3.30					3.28	3.32	3.36	3.30	4.45
24	89.8	70.0	79.9	1.27	1.72	1.84	1.59	1.95					2.99	3.11	2.86	3.22	5.09
25	82.2	66.4	74.3	1.52	2.52	2.61	2.74	2.65					4.04	4.13	4.26	4.17	4.40
26	73.5	60.3	66.9	0.25	0.91	0.86	0.88	0.66					1.16	1.11	1.13	0.91	3.62
27	76.5	57.5	67.0		4.20	4.10	4.50	4.69					4.20	4.10	4.50	4.69	3.58
28	84.7	57.5	71.1		4.11	4.22	4.32	4.38					4.11	4.22	4.32	4.38	4.04
29	72.5	61.0	66.8	0.20	3.40	3.58	3.52	3.94					3.60	3.78	3.72	4.14	3.58
30	82.5	57.0	69.8	7.62	2.41	2.56	2.43	2.30	7.74	6.45	6.20	3.76	2.29	3.73	3.85	6.16	3.88
31	73.5	52.0	62.8		2.70	2.58	2.44	1.68					2.70	2.58	2.44	1.68	3.11
Sept. 1	71.5	60.0	65.8	2.29	2.39	2.39	2.28	2.17					4.68	4.68	4.57	4.46	3.41
2	79.0	57.8	68.4		3.37	3.23	3.38	2.84					3.37	3.23	3.38	2.84	3.64
3	81.3	57.0	69.1		3.54	3.85	4.23	4.20					3.54	3.85	4.23	4.20	3.74
4	84.2	59.6	71.9		4.52	4.08	4.24	4.35					4.52	4.08	4.24	4.35	4.04
5	75.8	59.6	67.7		2.88	3.02	2.77	–					2.88	3.02	2.77	–	3.54
6	82.0	62.5	72.2		3.83	3.94	3.85	–					3.83	3.94	3.85	–	4.00
7	87.1	61.5	74.3		3.38	3.42	3.47	–					3.38	3.42	3.47	–	4.22
8	74.8	59.6	67.2		3.74	3.86	3.67	–					3.74	3.86	3.67	–	3.43
9	83.7	69.2	76.4		3.36	3.60	3.62	–					3.36	3.60	3.62	–	4.49
10	85.9	71.3	78.6		3.06	3.29	3.67	–					3.06	3.29	3.67	–	4.71
11	85.2	70.0	77.6		2.26	2.31	2.44	–					2.26	2.31	2.44	–	4.56
12	82.8	66.2	74.5		2.26	2.05	2.39	–					2.26	2.05	2.39	–	4.10
13	81.0	60.2	70.6	0.76	1.04	0.84	1.06	–					1.80	1.50	1.82	–	3.68
14	80.0	65.0	72.5		3.41	3.15	3.34	–					3.41	3.15	3.34	–	3.88
15	77.6	49.8	63.7	4.83	0.88	0.84	1.06	–	3.94	2.30	2.87	–	1.77	3.37	3.02	–	2.94
16	66.5	48.0	57.2		2.39	2.04	2.34	–					2.39	2.04	2.34	–	2.29
17	75.4	53.0	64.2		2.70	2.66	2.61	2.30					2.70	2.66	2.61	2.30	3.02
18	78.5	66.0	72.2		2.34	2.38	2.57	2.66					2.34	2.38	2.57	2.66	3.82
19	77.5	50.6	64.0	7.11	0.67	0.55	0.64	1.99	7.00	6.70	6.70	–	0.78	0.96	1.05	–	3.00
20	71.5	55.0	63.2		0.75	0.49	0.62	2.34					0.75	0.49	0.62	2.34	2.86
21	78.8	53.0	65.9	33.53	0.84	0.71	0.75	0.97	28.70	26.60	26.90	–	5.67	7.64	7.38	–	3.26
22	51.9	33.0	42.4		1.04	0.51	0.49	0.13					1.04	0.51	0.49	0.13	0.81
23	57.2	40.4	48.8		1.95	1.78	1.78	1.68					1.95	1.78	1.78	1.68	1.41
24	68.7	37.0	52.8		0.44	2.14	1.99	2.17					0.44	2.14	1.99	2.17	1.82
25	54.0	32.8	43.4		2.78	2.39	2.30	2.54					2.78	2.39	2.30	2.54	0.90
26	53.5	33.0	43.2		2.21	2.21	2.05	2.44					2.21	2.21	2.05	2.44	0.90
27	52.0	31.5	41.8		2.05	2.14	2.01	2.44					2.05	2.14	2.01	2.44	0.80
28	57.9	47.2	52.6	1.52	1.55	1.59	1.59	1.90					3.07	3.11	3.11	3.42	1.68
29	57.0	33.4	45.2	0.76	0.35	0.24	0.18	0.04	0.60	0.80	1.02	0.22	0.51	0.20	−0.08	0.58	0.99
30	47.9	30.5	39.2		1.48	1.35	1.46	1.53					1.48	1.35	1.46	1.53	0.47
					Tank D omitted from record hereafter												
Oct. 1	58.0	45.0	51.5		1.97	1.95	1.77						1.97	1.95	1.77		1.57
2	64.2	39.2	51.7		1.86	1.91	1.73						1.86	1.91	1.73		1.57
3	64.5	47.5	56.0		1.06	1.06	1.17						1.06	1.06	1.17		2.04
4	73.0	55.2	64.1		1.24	1.15	1.24						1.24	1.15	1.24		2.82
5	73.9	55.0	64.4		1.66	1.50	1.66						1.66	1.50	1.66		2.78
6	77.3	56.2	66.8		1.77	1.68	1.75						1.77	1.68	1.75		3.07
7	79.3	56.8	68.0		1.84	1.70	1.75						1.84	1.70	1.75		3.13
8	65.9	37.0	51.4		2.23	2.10	2.21						2.23	2.10	2.21		1.52
9	54.4	37.2	45.8		1.75	1.70	1.77						1.75	1.70	1.77		1.04
10	59.2	40.0	49.6		1.66	1.62	1.64						1.66	1.62	1.64		1.41
11	63.7	45.2	54.4		1.53	1.57	1.57						1.53	1.57	1.57		1.79

TABLE I—*Concluded*

DAILY VALUES OF EVAPOTRANSPIRATION—TORONTO, 1947—*Concluded*

Date	Temperature			P (mm.)	Water added (mm.)				Overflow (mm.)				Evapotranspiration (mm.)				
	Max.	Min.	Mn.		A	B	C	D	A	B	C	D	A	B	C	D	Computed
Oct. 12	69.0	51.7	60.4		0.97	1.00	0.97						0.97	1.00	0.97		2.32
13	69.5	41.5	55.5	4.83	0.18	0.18	0.02		2.92	2.66	2.48		2.09	2.35	2.37		1.86
14	68.6	45.0	56.8		1.24	1.00	1.08						1.24	1.00	1.08		2.04
15	75.0	49.8	62.4		0.31	1.15	1.06						0.31	1.15	1.06		2.48
16	75.6	50.3	63.0		1.57	1.02	1.06						1.57	1.02	1.06		2.54
17	75.2	56.1	65.6		0.89	0.87	0.85						0.89	0.87	0.85		2.73
18	71.2	60.8	66.0	1.02	0.36	0.37	0.29		0.49	0.40	0.60		0.89	0.99	0.71		2.82
19	74.5	40.5	57.5		1.24	1.09	1.20						1.24	1.09	1.20		2.00
20	75.8	46.4	61.1		1.99	1.90	1.96						1.99	1.90	1.96		2.34
21	66.7	46.6	56.6		1.63	1.63	1.70						1.63	1.63	1.70		1.89
22	73.0	55.8	64.4		1.00	1.04	1.06						1.00	1.04	1.06		2.58
23	61.9	32.7	47.3		2.06	2.04	2.00						2.06	2.04	2.00		1.16
24	50.0	36.9	43.4		1.17	1.22	1.28						1.17	1.22	1.28		0.80
25	60.0	40.0	50.0		0.73	0.73	0.75						0.73	0.73	0.75		1.32
26	68.0	49.0	58.5		0.80	0.80	0.84						0.80	0.80	0.84		2.02
27	72.0	54.0	63.0	0.76	0.75	0.75	0.73						1.51	1.51	1.49		2.44
28	65.5	54.0	59.8	13.72	0.04	0.03	0.02						13.76	13.75	13.74		2.18
29	58.0	49.0	53.5		–	–	–						–	–	–		1.57
30	49.0	42.0	45.5	10.67	0	0	0		22.90	22.50	23.20		−12.23	−11.83	−12.53		0.95
31	48.2	32.2	40.2		0.47	0.20	0.29						0.47	0.20	0.29		0.52
Nov. 1	52.6	34.7	43.6		0.80	0.73	0.75						0.80	0.73	0.75		0.77
2	54.8	38.0	46.4		0.66	0.66	0.62						0.66	0.66	0.62		1.02
3	55.8	44.2	50.0		0.71	0.71	0.84						0.71	0.71	0.84		1.27
4	51.1	46.5	48.8	5.33	0	0	0						–	–	–		1.18
5	52.8	48.6	50.7	4.32	0	0	0		8.22	7.64	8.36		1.43	2.01	1.29		1.21
6	56.1	40.8	48.4	5.33	0.07	0.03	0.07		5.10	5.35	5.25		0.30	0.01	0.15		1.18
7	57.2	37.0	47.1	1.52	0.09	0.04	0.02						1.61	1.56	1.54		0.99
8	46.4	31.0	38.7		–	–	–						–	–	–		0.41
9	40.0	28.8	34.4		2.74	1.59	1.88		1.15	1.15	1.06		1.59	0.44	0.82		0.16
10	50.2	39.2	44.7		0.38	0.42	0.44						0.38	0.42	0.44		0.82
11	50.0	31.0	40.5	10.41	0.09	0.04	0.04		9.55	9.20	9.65		0.95	1.25	0.80		0.49
12	43.0	30.7	36.8		0.57	0.19	0.15						0.57	0.19	0.15		0.33
13	40.8	24.2	32.5		1.10	0.58	1.24						1.10	0.58	1.24		0
14	39.9	24.5	32.2		1.33	0.44	0.89						1.33	0.44	0.89		0

The most important observation was that the water losses measured by the evapotranspirometers were of the same order of magnitude as those computed from the Thornthwaite formula. The total monthly water losses for the period of observation are given in Table II.

The potential evapotranspiration computed from the formula seems to be consistently a little greater than the actual water loss. Fig. 4 shows accumulated measured potential evapotranspiration compared with the computed during a sample period—July 31 to Aug. 15. The daily measured water use differs from the computed, yet totals for the period shown in Fig. 4 are remarkably similar.

TABLE II

TOTAL MONTHLY WATER LOSSES

	Tank A, Timothy		Tank B, Timothy		Tank C, Crested wheat		Tank D, Crested wheat		Computed	
	Cm.	In.	Cm.	In.	Cm.	In.	Cm.	In.	Cm.	In.
June (6 days)	2.6	1.0	2.6	1.0	2.8	1.1	2.7	1.1	2.9	1.1
July	12.0	4.7	12.7	5.0	11.6	4.6	12.2	4.8	13.0	5.1
Aug.	11.0	4.3	(12.0)	4.7	11.6	4.6	12.2	4.8	13.4	5.3
Sept.	7.8	3.1	8.1	3.2	8.2	3.2	—	—	8.6	3.4
Oct.	4.1	1.6	4.0	1.6	4.0	1.6	—	—	6.1	2.4
Nov. (14 days)	1.1	0.4	0.9	0.4	1.0	0.4	—	—	1.0	0.4
Total	38.6	15.1	40.3	15.9	39.2	15.5	—	—	45.0	17.7

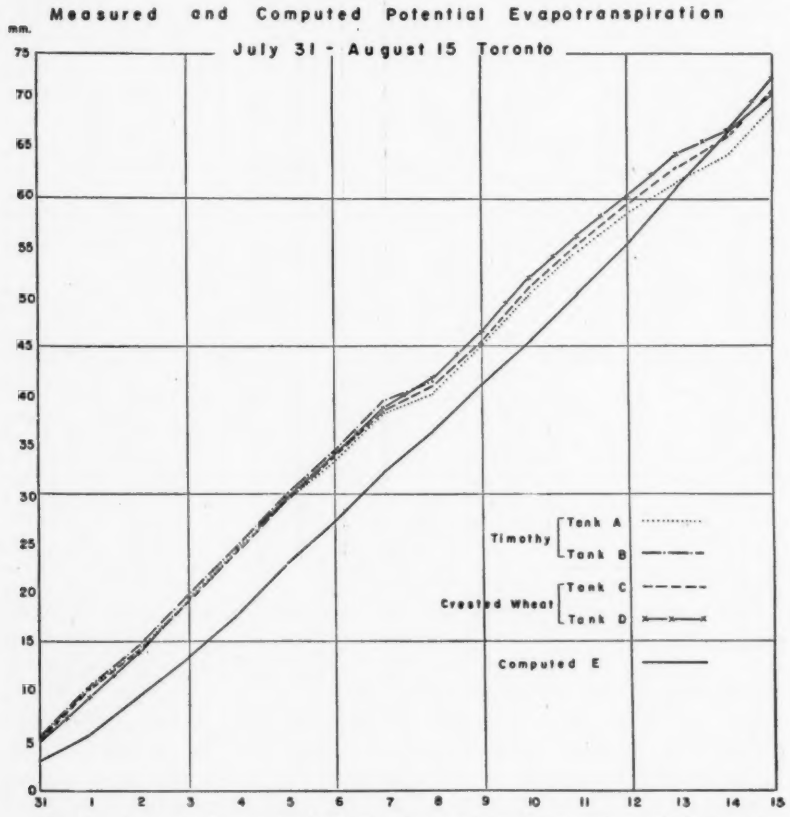

FIG. 4. *Accumulated water loss (July 31 to Aug. 15) from timothy and crested wheat tanks, compared with accumulated computed water loss. Readings from tank B discontinued Aug. 8 because of leak.*

Results for Individual Days

It is interesting to compare the relation between measured and computed E with current weather, air masses, humidity, and wind. The following example illustrates different types of weather during the two weeks mentioned above and the resulting evapotranspiration.

On July 31 a polar continental air mass was moving into the Toronto area, the mean temperature was 58°, and the maximum 71° F. The wind was northwest at 16 m.p.h. the mean relative humidity was 64 and the measured 'E' of 5.1 to 5.5 was considerably higher than the computed E of 2.8 mm.

By Aug. 1, the cool air mass had covered Toronto, winds were north at 5 m.p.h. and the relative humidity reached a low of 55, with the maximum temperature 67 and the mean 57. Measured E varied from 4.8 to 5.0, again higher than the computed E of 2.7 mm.

By Aug. 2, the center of the high had moved to upstate New York, there was no wind at Toronto and relative humidity averaged 68. The mean and maximum air temperatures were higher, 64° and 74° F. respectively, and the measured E of 4.0 to 4.2 mm. was very little higher than the computed of 3.5 mm.

A different type of weather characterized Toronto from *Aug. 11 to 14.*

On Aug. 11, a tropical maritime high was centered just east of Toronto. There was no wind, a relative humidity of 78, a mean temperature of 75°, and a maximum of 86° F. The measured E was 3.5 to 4.0 mm., slightly lower than the computed E of 4.7 mm.

By Aug. 12, the high had moved over the Carolinas, hot gulf air was drawn north to Toronto and the maximum temperature reached 93°, while the mean for the day was 82°. Average wind velocity was 0, relative humidity 70, and the measured E was 3.5 to 3.7 mm., while the computed was 5.6 mm.

On Aug. 13 and 14, the high was stationary over the Carolinas and the same conditions prevailed in Toronto. Measured evapotranspiration on the 13th was 4.3 to 4.6 mm.; the computed 5.8. On the 14th the discrepancy between measured and computed evapotranspiration was the greatest. Measured E was only 1.7 to 2.0, the computed 5.4 mm.

From these two examples it appears that when tropical maritime air masses covered the station, the measured potential evapotranspiration was lower than the computed and when cooler continental, less humid air masses were present, the measured potential evapotranspiration was higher than the computed. On days with intermediate weather conditions, the measured water loss was similar to the computed. For example, on July 30, when the mean temperature was 74°, and average relative humidity 69°, the measured E was 4.75 – 4.9 mm. and the computed 4.75 mm.

Probable Sources of Error

The amount of soil originally placed in the tanks was judged sufficient to allow settling but after several heavy rains in June, the soil settled 1 to 2 in.

below the general surface level. In this way the natural microclimate of the grasses may have been slightly modified.

When the daily readings were begun, it soon became obvious that after a rain, a certain unknown amount of water was held in the soil masses of each tank. It did not appear as surplus in the overflow tank, but supplied part of the moisture required for evapotranspiration in succeeding days. The amount varied with the four tanks and with different amounts of rainfall and resulted in uncertainty of the value of E for the day when precipitation occurred and at least one day following.

During the season, there was evidence that the precipitation sample from one 4.5 in. diameter rain gauge was not an adequate sample of the rain falling on the tanks. Because of the considerable weight given this figure in the computation, and the frequent rainy days (40 out of 140 during the period of observation), a larger rain sample should be taken.

Conclusion

The present progress report on the Ontario Research Foundation evapotranspirometer experiments may prove helpful to others wishing to make similar measurements. The apparatus is inexpensive and simple to construct, yet it makes possible accurate daily readings of potential water need. In this respect it is a new and very important climatological instrument.

The first season of experiment indicates that there is no difference in the evapotranspiration from similar areas of different grasses, even though one has sparse and the other luxuriant growth.

The experiment has shown that the Thornthwaite formula gives values of potential water need of the right order of magnitude for Toronto. Computed and measured potential evapotranspiration for weekly or monthly periods were reassuringly similar. Daily values given by the formula are not accurate but with sufficient data, the present formula could be revised.

References

1. Contreras Arias, A. Observaciones de evapotranspiracion. Sec. Agr. fomento comision nacl. irrigacion, Tacubaya, Mexico. 1945.
2. Sanderson, M. The climates of Canada according to the new Thornthwaite classification. *To be published.*
3. Thornthwaite, C. W. An approach toward a rational classification of climate. Geog. Rev. 38 : 55–94. 1948.
4. Wilm, H. G., Thornthwaite, C. W. et al. Report of the committee on evaporation and transpiration 1945–46. Trans. Am. Geophys. Union, 27 : 721-723. 1946.

NOTES

PHOSPHORUS DEFICIENCY IN RELATION TO THE NITRATE REDUCTION TEST

Comment on a Paper by Isobel Dimmick

The report by Dimmick (1) on the inability of certain types of bacteria to reduce nitrates when cultured on a medium containing calcium and their ability to reduce nitrate to nitrite in a similar medium containing either no calcium or an appreciably reduced amount, calls for comment. Dimmick considers that as in the preparation of the medium given in The Manual of Methods for the Pure Culture Study of Bacteria (2) the calcium is precipitated as an insoluble phosphate, the medium is then deficient in available phosphorus, not necessarily for growth of bacteria but possibly for the specific physiological reaction of the reduction of nitrate to nitrite. Further it is stated that there are many other media, used for a variety of purposes, that include in their composition phosphates together with comparatively large amounts of calcium, and that it is possible that bacteria growing in such media may suffer from phosphate deficiency.

Dimmick's interpretation of her results raises not only the question of the chemical composition of synthetic media but the usefulness and interpretation of differential tests in general. In the early days of bacteriology incorporation of different ions in a bacteriological medium was based largely on knowledge of the requirements of plants. Unfortunately often little regard was paid to the amounts of chemicals added and their compatability. Worse examples exist than the incorporation of phosphate together with relatively large amounts of calcium under conditions that result in the precipitation of insoluble calcium phosphate. Some synthetic media, valued by their originators as being strictly reproducible, contain in addition to phosphate and calcium appreciable amounts of iron and magnesium; in these media a large proportion of the cations are precipitated as insoluble phosphates during preparation. Little attention appears to have been paid to the quantities of ingredients added in relation to the actual requirements of the bacteria and rarely any to the C/N ratio provided in the medium.

Dimmick's inference that the insoluble calcium phosphate produced in the 'Manual of Methods' nitrate medium limits the reduction of nitrate to nitrite by certain bacteria, by virtue of causing a phosphate deficiency in the medium, would have a wide application to bacteriology in general. It is therefore desirable to consider the phenomenon of nitrate reduction and to assess the importance of phosphate.

Nitrate Reduction by Bacteria

From the review of bacterial denitrification by Lloyd (3) and the work of Meiklejohn (4) the presence of nitrite in a nitrate medium can infer (*a*)

transient production of nitrite previous to further reduction i.e. a stage in the process of denitrification; (*b*) accumulation of nitrite due to conditions (acidity, etc.) preventing further reduction, or (*c*) a specific reaction in which nitrate is reduced only to nitrite, analogous to the specificity of *Nitrosomonas* reaction. Whereas there is little knowledge of reaction (*c*) Meiklejohn provides considerable information on (*a*) and (*b*). In brief, the results obtained with two species of denitrifying bacteria showed that although several organic compounds acted as substrates for growth not all would act as hydrogen donators for the denitrification reaction. With glucose and lactate as carbon sources denitrification proceeded to gaseous nitrogen; with lactose the end product was nitrite. It is clear from Meiklejohn's results that with a denitrifying culture the detection of nitrite in the medium depends not only on the period of incubation but on the specific carbon source used. It is of importance to note that Meiklejohn used a medium incorporating 0.01% calcium chloride and adjusted to pH 8.0 before steaming.

Comparison of Different Synthetic Nitrate Media

The Reaction of the Medium.—No precise details are provided by the Manual for the preparation of the synthetic liquid medium, nor by Dimmick for the preparation of the solid synthetic medium, particularly in regard to the adjustment of the pH value. In the first place liquid preparations of the Manual, Jensen's, and Dimmick's proposed medium were prepared. Part of each was sterilized by autoclaving in a pressure cooker for 15 min. at 15 lb. pressure, and part by steaming for one hour on three successive days. The pH values were determined by indicators.

TABLE I

Effect of heating on the pH values of synthetic nitrate media

Medium	pH		
	Before heating	After steaming	After autoclaving
Manual	7.2	6.5	5.7
Jensen's	8.5	—	6.9
Dimmick's	8.4	7.3	6.8

Autoclaving produced an appreciable precipitate in Jensen's medium owing to the precipitation of magnesium phosphate. From Table I it can be seen that the acid reaction of the Manual medium, following sterilization, would be unfavorable for the growth of many types of bacteria.

The Amount of Phosphate Precipitated.—In order to test rather than speculate upon the amount of water-soluble phosphorus in the precipitate-free media, analyses were carried out on the clear supernatant liquor of both the Manual and Jensen's media.

The results (Table II) show that approximately half the phosphorus added to either Jensen's or the Manual medium is precipitated; in both media the amounts available for bacterial growth should be in excess of requirements.

Growth Tests.—The work of Dimmick was repeated. Solid media were prepared: (*A*) Manual, (*B*) Manual, sodium nitrate replacing potassium nitrate, (*C*) Manual, sodium chloride replacing calcium chloride, (*D*) Dimmick's

TABLE II

AMOUNTS OF WATER-SOLUBLE PHOSPHORUS IN PRECIPITATE-FREE MEDIA

Medium	Phosphorus (mgm./liter P)	
	Added according to formula	Found in precipitate-free liquor after autoclaving
Jensen's	178	88
Manual	89	40

proposed medium, and (*E*) Manual adjusted to give a pH value of 7.2 after autoclaving. Colorimetric determinations of the pH values of the prepared media were (*A*) and (*B*), 5.8; (*C*) and (*D*), 6.7. The slopes of the agar media were streaked with cultures obtained from soil, mostly of the *Bacterium globiforme* type, and including *B. globiforme* Conn, and other similar types used in previous work (5). The amounts of growth were compared after incubation periods of three and six days at 20° C. and the test for nitrite applied on the latter occasion. There was little difference in the density of growth on the various media but in general (*A*) produced least growth and (*E*) was most favorable; the beneficial effect of the more neutral reaction of (*E*) was shown clearly. Of the 22 cultures examined 14 gave positive nitrite reactions to some degree in all media and two gave positive results in media (*B*), (*C*), and (*D*) only; one was positive in (*A*) only. Negative cultures were treated with zinc dust to ascertain whether the nitrate of the medium remained or had been reduced beyond the stage of nitrite. Of the five cultures that gave negative results in all media, four were found to have had no action on the nitrate; the fifth culture had reduced the nitrate beyond nitrite in media (*A*), (*C*), and (*E*). It was found that of the three cultures that gave anomalous results the negative reactions of two were explained by the reduction of nitrate beyond nitrite but the third culture had been unable to reduce the nitrate in media (*A*) and (*E*). Thus the only significant results of the test were that one culture could not reduce nitrate in media (*B*) and (*D*), and one in media (*A*) and (*E*) at the temperature and incubation period of the test.

A further test was carried out using 16 cultures of bacteria capable of multiplying in stored water and able to grow on a medium containing nitrogen

in inorganic form. Media (*A*) to (*D*) were employed. There was no obvious difference in the density of growth produced in the different media. The nitrite results with these cultures were not so clearly defined as was the case with the soil organisms. In some instances the test was only very faintly positive (0.2γ) and such reactions had to be considered as positive tests. Of the 16 cultures eight gave positive reactions in all media, including two cultures that reduced the nitrate beyond nitrite, and one culture was consistently negative. Of the remaining seven cultures four gave negative reaction on (*A*), four on (*B*), one on (*C*), and two on (*D*). Three of the four cultures giving negative tests on (*A*) were later found to give positive results when grown on (*E*), the medium of identical composition but adjusted to pH 7.2.

The most relevant point was that in some instances negative nitrite tests were due to the reduction of nitrate beyond nitrite, and hence in order to demonstrate the production of nitrite it is necessary to test the culture before reduction of all the nitrate is complete. To demonstrate this point several slopes of the various media were inoculated with a culture of *B. globiforme* Conn and nitrite tests were carried out after incubation for different periods at a temperature of 20° C. The phenomenon was common with other denitrifying cultures.

TABLE III

REDUCTION OF NITRATE IN DIFFERENT MEDIA BY *Bacterium globiforme* CONN

Medium	Period of incubation (days)				
	1	2	3	4	6
(*A*) Manual ($CaCl_2$)	++	++	−	−	−
(*C*) Manual (NaCl)	+	+++	−	−	−
(*D*) Dimmick	++	+++	+++	−	−

Note: + = NO_2 *positive;* − = NO_3 *negative.*

CONCLUSIONS

The results obtained in this work show that it is extremely unlikely that any inferiority of the Manual of Methods nitrate medium is due to phosphorus deficiency, either for the growth of bacteria, or for some physiological process affecting nitrate reduction. On the other hand there is strong evidence to suggest that inability to demonstrate the presence of nitrite in a culture of a nitrate-reducing bacterium is accounted for by either an acidic reaction of the medium or, in the case of denitrifying bacteria, by the fact that nitrate may have been reduced beyond nitrite. The importance of using a medium adjusted to the alkaline side of neutrality cannot be too strongly emphasized. In recording the ability or inability of an organism to reduce nitrate the experimental conditions should be stated in full.

References

1. DIMMICK, I. Phosphorus deficiency in relation to the nitrate reduction test. Can. J. Research, C, 25 : 271-273. 1947.
2. COMMITTEE ON BACTERIOLOGICAL TECHNIQUE OF THE SOCIETY OF AMERICAN BACTERIOLOGISTS. Manual of methods for pure culture study of bacteria. Leaflet II. Biotech Publications, Geneva, N.Y. 1933.
3. LLOYD, B. Bacterial denitrification: an historical and critical survey. J. Roy. Tech. Coll. Glasgow, 2 : 530-550. 1931.
4. MEIKLEJOHN, J. Aerobic denitrification. Ann. Applied Biol. 27 : 558-573. 1940.
5. TAYLOR, C. B. Further studies of *Bacterium globiforme* and the incidence of this type of organism in Canadian soils. Soil Sci. 46 : 307-320. 1938.

C. B. TAYLOR

RECEIVED MARCH 16, 1948.

FRESHWATER BIOLOGICAL ASSOCIATION,
WRAY CASTLE, AMBLESIDE, ENGLAND.

CANADIAN JOURNAL OF RESEARCH

Notes on the Preparation of Copy

GENERAL:—Manuscripts should be typewritten, double spaced, and the **original and one extra copy** submitted. Style, arrangement, spelling, and abbreviations should conform to the usage of this Journal. Names of all simple compounds, rather than their formulae, should be used in the text. Greek letters or unusual signs should be written plainly or explained by marginal notes. Superscripts and subscripts must be legible and carefully placed. Manuscripts should be carefully checked before being submitted, to reduce the need for changes after the type has been set. If authors require changes to be made after the type is set, they will be charged for changes that are considered to be excessive. **All pages, whether text, figures, or tables, should be numbered.**

ABSTRACT:—**An abstract of not more than about 200 words, indicating the scope of the work and the principal findings, is required.**

ILLUSTRATIONS:

(i) *Line Drawings:*—All lines should be of sufficient thickness to reproduce well. Drawings should be carefully made with India ink on white drawing paper, blue tracing linen, or co-ordinate paper **ruled in blue only**; any co-ordinate lines that are to appear in the reproduction should be ruled in black ink. Paper ruled in **green, yellow, or red should not be used** unless it is desired to have all the co-ordinate lines show. Lettering and numerals should be neatly done in India ink preferably with a stencil (**do not use typewriting**) and be of such size that they will be legible and not less than one millimetre in height when reproduced in a cut three inches wide. All experimental points should be carefully drawn with instruments. Illustrations need not be more than two or three times the size of the desired reproduction, but the ratio of height to width should conform with that of the type page. **The original drawings and one set of small but clear photographic copies are to be submitted.**

(ii) *Photographs:*—Prints should be made on glossy paper, with strong contrasts; they should be trimmed to remove all extraneous material so that essential features only are shown. Photographs should be submitted **in duplicate**; if they are to be reproduced in groups, one set should be so arranged and mounted on cardboard with rubber cement; the duplicate set should be unmounted.

(iii) *General:*—**The author's name, title of paper, and figure number should be written in the lower left hand corner (outside the illustration proper) of the sheets on which the illustrations appear.** Captions should not be written on the illustrations, but typed on a separate page of the manuscript. All figures (including each figure of the plates) should be numbered consecutively from 1 up (arabic numerals). **Each figure should be referred to in the text.** If authors desire to alter a cut, they will be charged for the new cut.

TABLES:—Titles should be given for all tables, which should be numbered in Roman numerals. Column heads should be brief and textual matter in tables confined to a minimum. **Each table should be referred to in the text.**

REFERENCES:—**These should be listed alphabetically by authors' names, numbered in that order, and placed at the end of the paper.** The form of literature citation should be that used in the respective sections of this Journal. **Titles of papers should not be given in references listed in Sections A, B, E, and F, but must be given in references listed in Sections C and D.** The first page only of the references cited in papers appearing in Sections A, B, and E should be given. **All citations should be checked with the original articles.** Each citation should be referred to in the text by means of the key number; in Sections C and D the author's name and the date of publication may be included with the key number if desired.

The *Canadian Journal of Research* conforms in general with the practice outlined in the *Canadian Government Editorial Style Manual*, published by the Department of Public Printing and Stationery, Ottawa.

Reprints

Fifty reprints of each paper without covers are supplied free. Additional reprints, if required, will be supplied according to a prescribed schedule of charges. On request, covers can be furnished at cost.